BANKING UNDER LARGE EXCESS RESERVES

A structural approach

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McGill Desautels & Frankfurt School of Finance & Management

Quantitative Easing, Large Excess Reserves

Large-scale asset purchases or Quantitative Easing (QE):

- **Mechanism:** Central banks directly **purchase securities on the markets.**
- **Objectives**: Shore up prices, stabilize demand, lower market interest rates. Broadly, **stimulate the economy.**
- **Consequences**: Injection of **€5 trillion in central bank reserves** into the eurozone banking system.

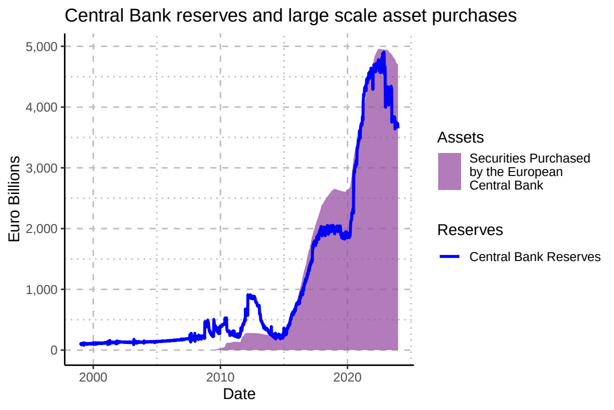

Figure: Simplified ECB balance sheet

Structural Break | Further SB | Unsecured Mkt | Rates inversion | Further RI | QETrade

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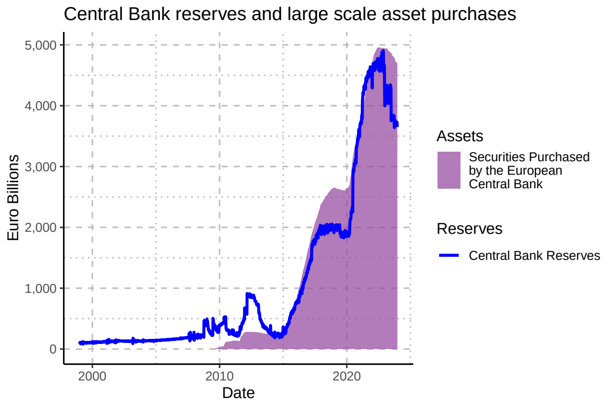
- **Consequences**: Injection of **€5 trillion in central bank reserves** into the eurozone banking system.
- **Can too much QE backfire?** Diamond et al. (2024), d'Avernas et al. (WP 2024), Acharya et al. (WP 2024)



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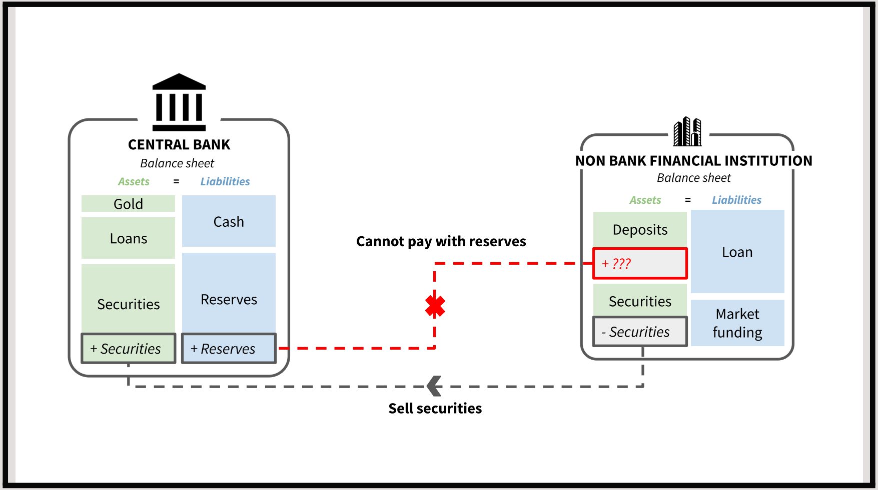
Quantitative Easing and the bank's balance sheet

A standard Quantitative Easing transaction



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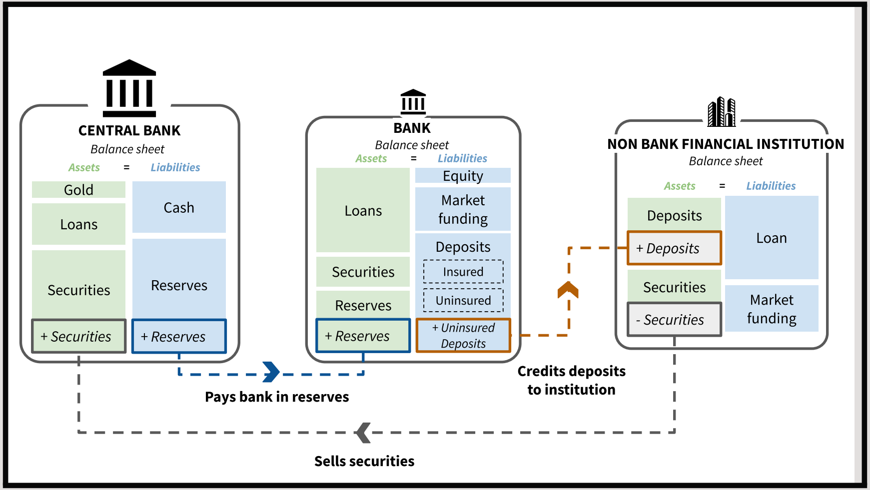

Basel regulation vs QE

Research Question

Can reserves issued from Quantitative Easing lead to decreased lending?

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Hypothesis: Reserves glut channel caused by interaction with Basel III.

It might be costly to hold large amounts of reserves due to regulatory constraints.

- Maximum leverage of banks **limited by Basel III regulation**.
- **Regulatory costs**: Composition of the balance sheet constrained by regulatory requirements.
- **Prediction**: Reserves injected during QE might **crowd out** other assets and specifically bank lending.

Regulatory ratios and intuition

Basel III ratios:

- The Liquidity Coverage Ratio (LCR) ensures a bank has **enough liquid assets to cover outflows**:
  $LCR = \frac{Liquid\ Assets}{Net\ outflows}$
- The Leverage Ratio (LEV) or SLR **limits the maximum amount of leverage** a bank can take:
  $LEV = \frac{Core\ Equity}{Total\ Assets}$
- The Net Stable Funding ratio (NSF) ensures banks have sufficient **long-term funding** to finance **illiquid assets**:
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Trade-off intuition

- An increase in the quantity of **reserves** improves **the banks' liquidity**.
- Expanding the balance sheet **worsens** **the banks' leverage**.
- The increase in unstable deposits **worsens** **the net stable funding** of banks.

Contribution & Literature

Reserves & unconventional monetary policy

Reserves: Kashyap and Stein (2012), Arrata et al. (2020), Christensen and Krogstrup (2019), Copeland et al. (2019), Acharya et al. (2022), Nobili et al. (2024), Cesaratto, Febrero, and Pantelopoulos (2024), Baldo, Bucalossi, and Scalia (2017)

Unconventional monetary policy: Peydró, Polo, and Sette (2021), Martins, Batista, and Ferreira-Lopes, (2019), Orame, Ramcharan, and Robatto (2024), Bernardini and De Nicola (2024), Albertazzi, Nobili and Signoretti (2021)

Contribution: Quantify how much quantitative easing impacts the banks' cost function through regulatory constraints.

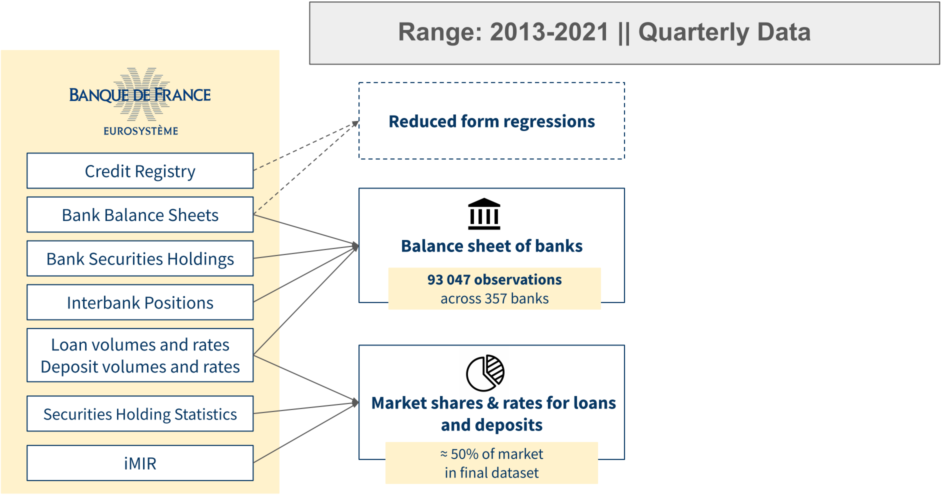
Structural models of Banking

Diamond et al. (2022), Wang et al. (Aug. 2022), Egan, Hortaçsu, and Matvos (2017), Xiao (2020), Bulligan et al. (2017)

Technical Contributions:

- Model of Eurozone banking sector with excess reserves and reserve trading costs.
- Structured cost function that incorporates regulatory constraints.

DATA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93 047 observations
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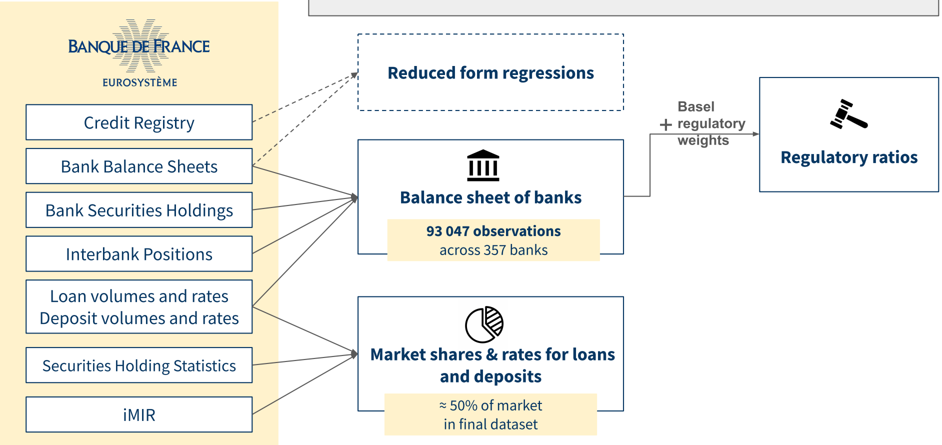

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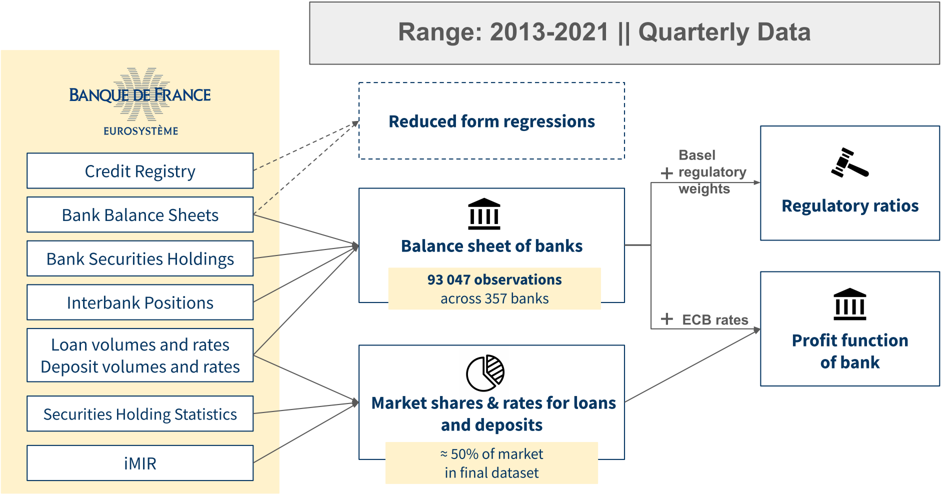
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+ Basel regulatory weights
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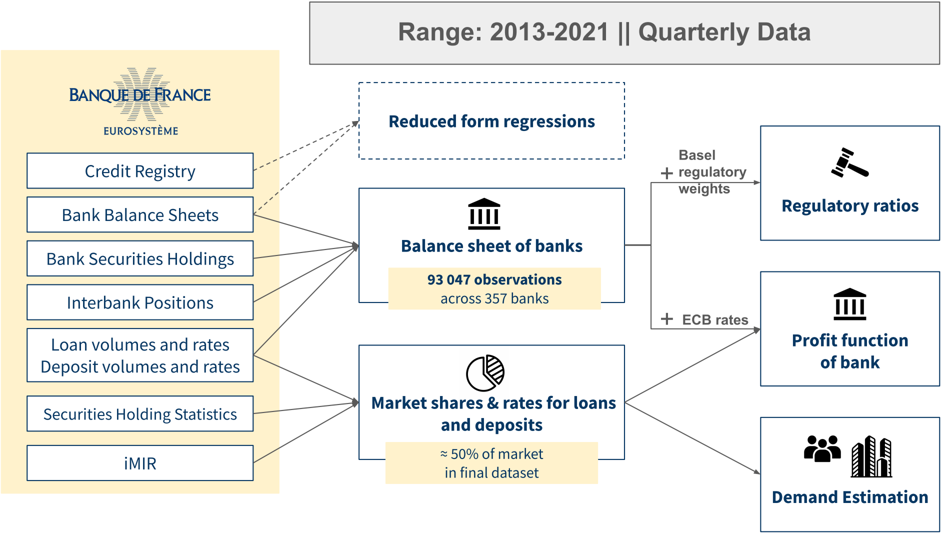
Regulatory ratios
Profit function of bank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Demand Estimation

PRELIMINARY EVIDENCE

Do reserves crowd out lending? Test setup

Regression equation :

$$Y_{ijt} = \alpha_0 ReserveShare_{j,t-1} + \alpha_1 \Delta ReserveShare_{jt} + \beta Z_{jt} + FE_{it} + \epsilon_{ijt}$$

With i = firms, j = banks, and t = time.

Dependent variable: Mid-point growth of credit

Growth rate of outstanding credit during 2019Q4-2021Q4 QE round.

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Endogeneity:

- Reserves are issued under expansionary monetary policy.
- Firms at high-reserves banks might be structurally different.

Solution:

- Leverage firms with multiple banks by including **Firm × time fixed effects.**

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- Firms at high-reserves banks might be structurally different.
- Banks' reserve take-up is possibly endogenous.

Solution:

- Leverage firms with multiple banks by including **Firm $\times$ time fixed effects.**
- Instrument exposure to QE with **share of financial clientele in 2014.** QETrade

Instrumented Regression

Back of the enveloppe calculation

- Share of reserves on the aggregate balance sheet increased from 6% to 15% over the period.
- Implies up to 30% loss in potential corporate lending provision.
- Up to 60 cents of lost corporate lending for each 1€ of reserves injected.

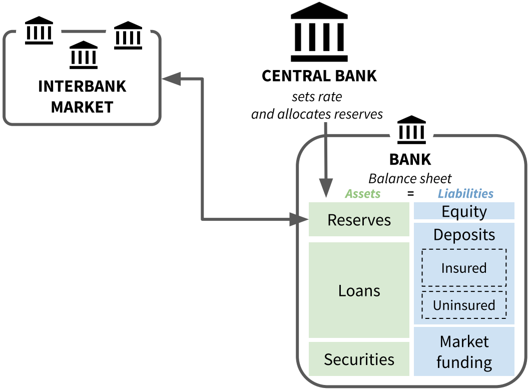
2019Q4-2021Q4 IV Regression

Dependent Variables:	Mid-point growth	
Model:	Base	IV
$ReserveShare_{j,t-1}$	-0.3021	-1.454*
	(0.2238)	(0.7651)
$\Delta ReserveShare_{jt}$	-1.472***	-3.382**
	(0.2112)	(1.536)
$TotalAssets_{t-1}$	0.0846***	0.1293***
	(0.0107)	(0.0300)
Firm fixed-effects	Yes	Yes
Observations	866,202	866,202
R^2	0.64582	0.63881
Within R^2	0.01965	
Wu-Hausman	/	244.7

Clustered at the bank level standard-errors in parentheses

MODEL

Model of the Banking System



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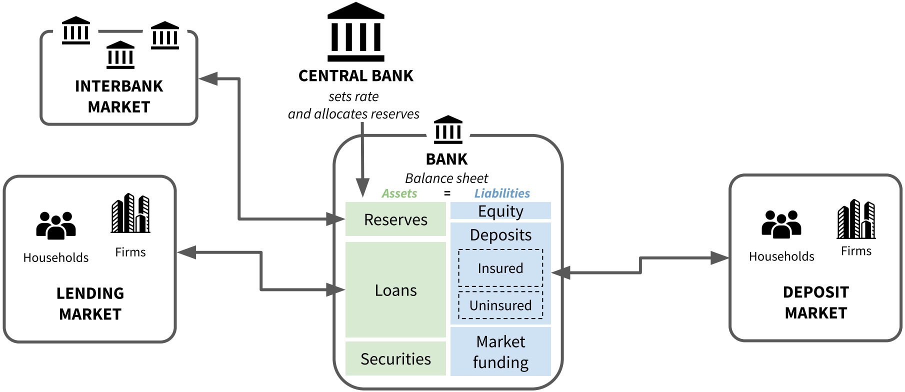

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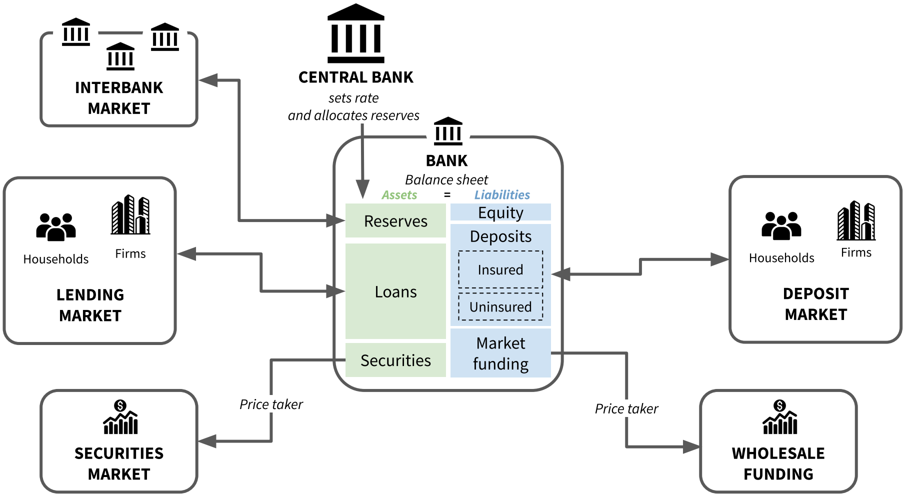

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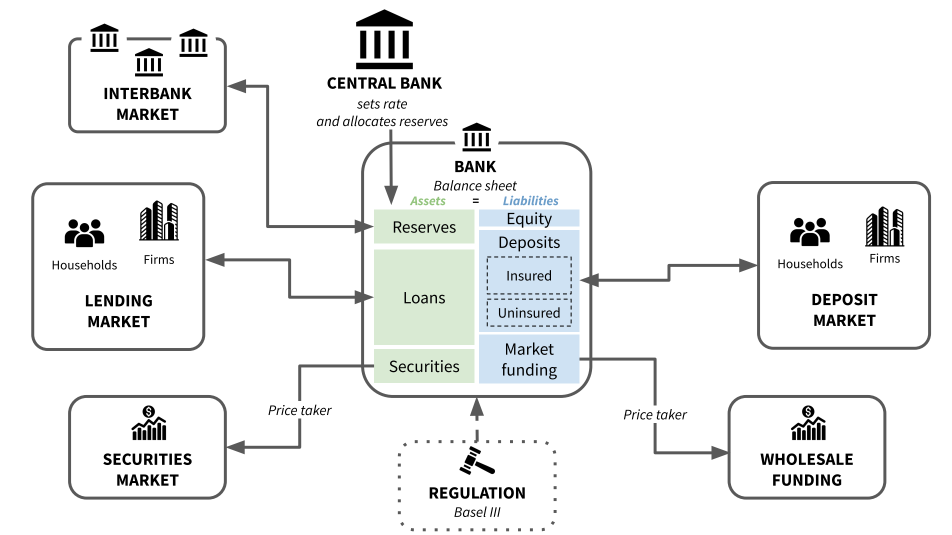

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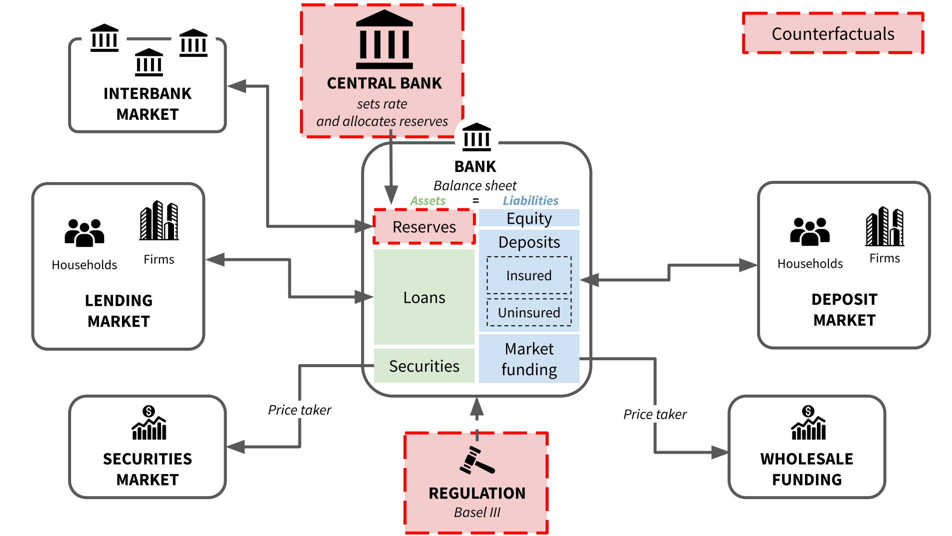

Banks

Balance-sheet approach

- Banks have to fund assets by issuing liabilities

$$\underbrace{\mathbf{1}'\mathbf{X}_{i,A}}_{\text{Assets}} + \underbrace{Q_{i,R}}_{\text{Reserves endowment}} = \underbrace{\mathbf{1}'\mathbf{X}_{i,L}}_{\text{Liabilities}} + \underbrace{E_i}_{\text{Equity}}$$

- Banks maximize their **net return on balance sheet positions** conditional on cost

$$\textbf{Profit}_{\textbf{i}} = \underbrace{\mathbf{X}'_{i,A}\mathbf{R}_{i,A}}_{\text{Return on assets}} - \underbrace{\mathbf{X}'_{i,L}\mathbf{R}_{i,L}}_{\text{Cost of liabilities}} - \underbrace{\Delta Q_{i,R}(R_{ITB} - R_{DF})}_{\text{Return on traded reserves}} - \underbrace{\mathcal{C}_i(\Delta Q_{i,R}, \mathbf{X}_i)}_{\text{Cost function}}$$

With

- $\mathbf{R}_{i,A}$ the interest rates on assets
- $\mathbf{R}_{i,D}$ the interest rates paid on deposits
- R_{ITB} the interbank rate, R_{DF} the deposit facility rate
- $\Delta Q_{i,R}$ the quantity of reserves borrowed on the interbank market.

The cost function

Conceptually: Captures max mean-variance portfolio subject to regulatory constraints.

- The shadow cost of a constraint k is captured by a smooth function of the regulatory ratio $\lambda_{ik} = \lambda_k(Ratio_{ik}) = \bar{\lambda}_k \exp\left(\frac{\text{Requirement}_k - \text{Ratio}_{ik}}{\text{Requirement}_k}\right)$

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$$\mathcal{C}_i(\Delta Q_{i,R}, \mathsf{X}_i) = \underbrace{\frac{1}{2}\frac{\varphi}{E_i}(\Delta Q_{i,R})^2}_{\text{Trading cost}} + \underbrace{\frac{1}{2}\frac{\gamma}{E_i}\mathsf{X}_i'\boldsymbol{\Sigma}\mathsf{X}_i}_{\text{Risk}} + \underbrace{\sum_k \lambda_{ik}\boldsymbol{\omega}_{X,k}'\mathsf{X}_i}_{\text{Shadow cost of regulation}}$$

With

- φ the monitoring/trading cost on the reserves market.
- γ the banks' risk aversion coefficient, $\boldsymbol{\Sigma}$ the variance-covariance of asset returns.
- $\boldsymbol{\omega}_{X,k}$ the vector of regulatory weights for constraint k.

Bank's optimization problem

Bank's problem:

$$
\begin{aligned}
\max_{\mathsf{X}_i,\Delta Q_{i,R}} \quad & \underbrace{\mathsf{X}_i'\mathsf{R}_i - \Delta Q_{i,R}(R_{ITB} - R_{DF})}_{\text{Net return on balance sheet positions}} \quad -\mathcal{C}_i(\Delta Q_{i,R}, \mathsf{X}_i) \\
s.t. \quad & \underbrace{\mathbf{1}'\mathsf{X}_{i,A} + Q_{i,R} = \mathbf{1}'\mathsf{X}_{i,L} + E_i}_{\text{Assets} = \text{Liabilities}} \\
with \quad & \mathcal{C}_i(\Delta Q_{i,R}, \mathsf{X}_i) = \underbrace{\frac{1}{2}\frac{\varphi}{E_i}(\Delta Q_{i,R})^2}_{\text{Trading cost}} + \underbrace{\frac{1}{2}\frac{\gamma}{E_i}\mathsf{X}_i'\mathbf{\Sigma}\mathsf{X}_i}_{\text{Risk}} + \underbrace{\sum_k \lambda_{ik}\boldsymbol{\omega}_{X,k}'\mathsf{X}_i}_{\text{Shadow cost of regulation}}
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F.O.C. ESTIMATION EQUATION

Note that the R.H.S of the F.O.C. is linear in unobserved parameters

$$\underbrace{R_i(X_{ijt}) + R_i'(X_{ijt})X_{ijt}}_{\text{Marginal Return}} = \gamma \underbrace{Risk_{ijt}}_{\sum_m \sigma_{jm} X_{im} / Ei} + \sum_k \bar{\lambda}_k \underbrace{RegulatoryCost_{k,ijt}}_{e^{(1-ratio_{ik})}(1-X_{ijt}\frac{\partial ratio_{ikt}}{\partial X_{ijt}})\omega_{jk}} + \lambda_{BS,it}$$

- $\lambda_{BS,it}$ is a bank-time-specific fixed-effect, denotes the shadow cost of the balance sheet constraint from the maximisation problem (i.e. $Assets = Liabilities$).
- σ_{jm} denotes the covariance of returns between item X_{ij} and item X_{im}.

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Regression Equation: pooled FE regression

$$Y_{ijt} = \gamma Risk_{ijt} + \Lambda' \mathbf{RegCost}_{ijt} + FE_{it} + \epsilon_{it}$$

- With Y_{ijt} the marginal return, and $\mathbf{RegCost}_{ijt}$ a vector of constraints costs.
- **Given a demand side to estimate the markups in the marginal return, we can estimate the bank's cost function parameters.**

RESULTS

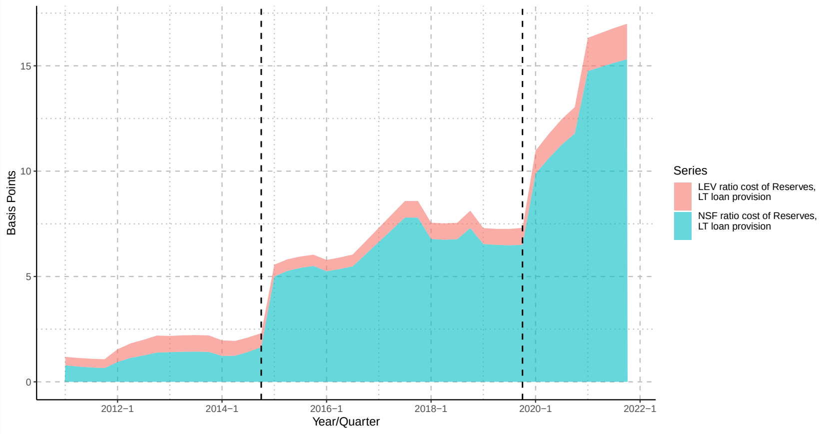
Regulatory cost of reserves, LT lending, average lender

Result 1

- The regulatory costs of QE increased over time.
- Long-term lending: 17 basis point increase in marginal cost in 2021.

Result 2

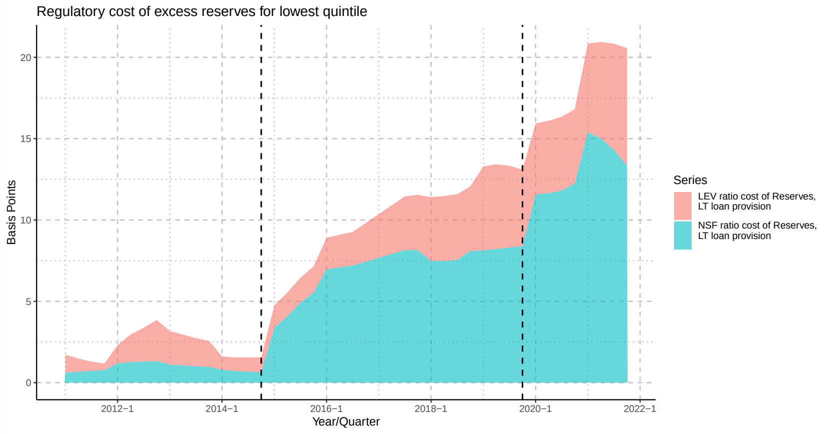
- NSF represented the majority of the cost increases.



Regulatory cost of reserves, LT lending, small banks

Result 3

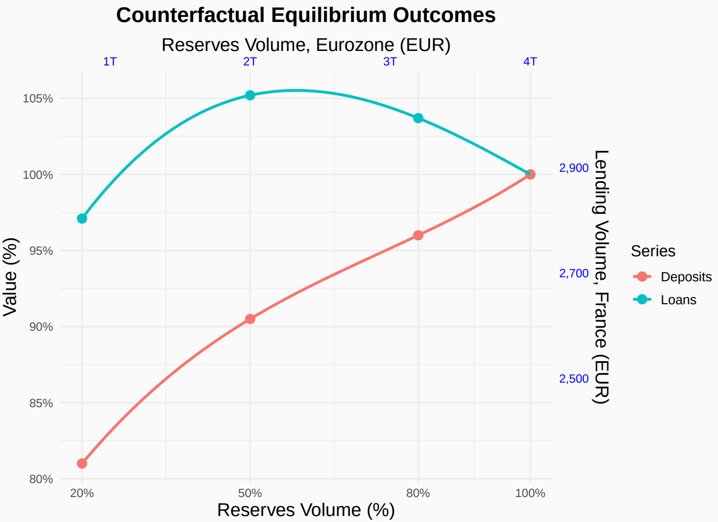
- Small banks are more affected by the increase in leverage.



Cost of regulation and counterfactuals

- **Counterfactuals:** 2021 Q4 data (before rate hikes), computed for 20%, 50% and 80% decrease in reserves.

Counterfactuals Recipe | Counterfactuals Computation



Take-away

Contribution: Regulation-based cost function -> Isolates the cost of regulation.

Results

- There is a threshold beyond which excess reserves become detrimental for lending.
- Once banks are liquid, benefits of additional reserves diminishes, but costs continues to increase.

Policy implications

- Leverage ratio relief -> easy to implement. (see Waltz 2024, Koont et al. 2021)
- ONRRP -> could target specific reserve levels. (see Cipriani et al. 2022)
- CBDCs at odds with regulation. (Resano 2024, Bitter 2024, Ahnert et al. 2023)

Thank You

APPENDIX

The demand side: empirical IO model of competition

- In market N, we have a uniform distribution of agents of with yield sensitivity α.
- Agents choose over banking products k to maximize their utility.

$$\max_{i \in \mathcal{I}} u_{ij} = \alpha_k R_{ik,Nt} + \beta C_{i,Nt} + \xi_{ik,Nt} + \epsilon_{ij}$$

- With
  - $R_{ik,Nt}$ the interest rate offered by bank i on product k
  - $C_{i,Nt}$ a vector of time-varying bank-characteristics
  - α_k the elasticity of demand for product k
  - $\xi_{ik,Nt}$ unobserved bank-product quality

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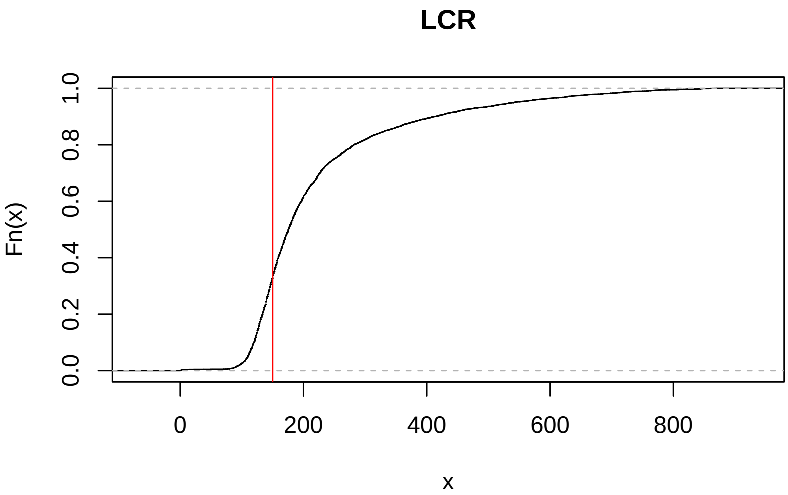
- Logit market shares : **imperfect competition**, from which we extract **markups**.

$$\log(\text{Market Share}_i) \propto \alpha_k R_{ik,Nt} + \beta C_{i,Nt} + \xi_{ik,Nt}$$

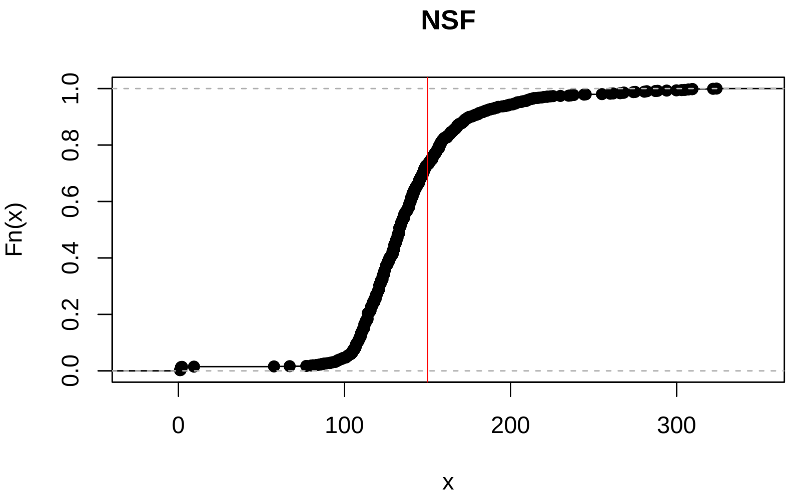
- **Instruments**: Granular IVs, Hausman instruments.

Deposit Demand Loan Demand

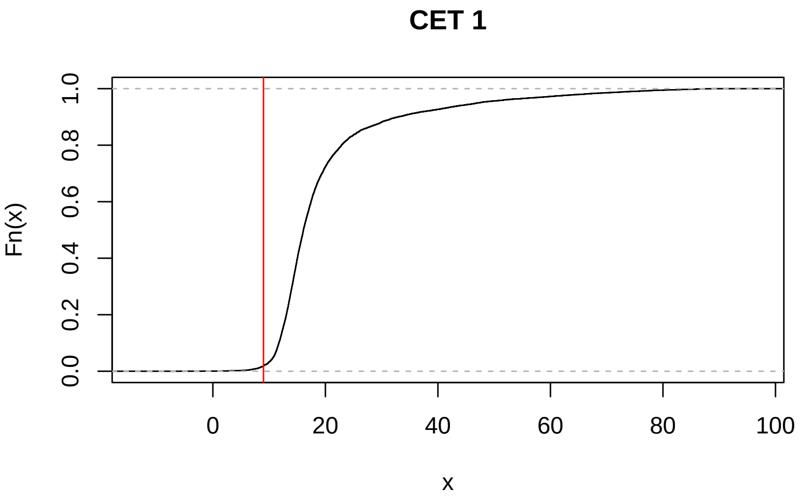
LCR



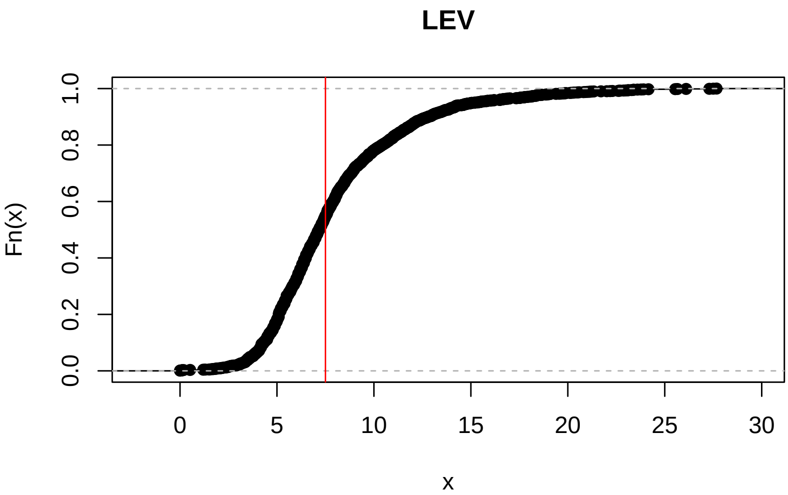
NSF



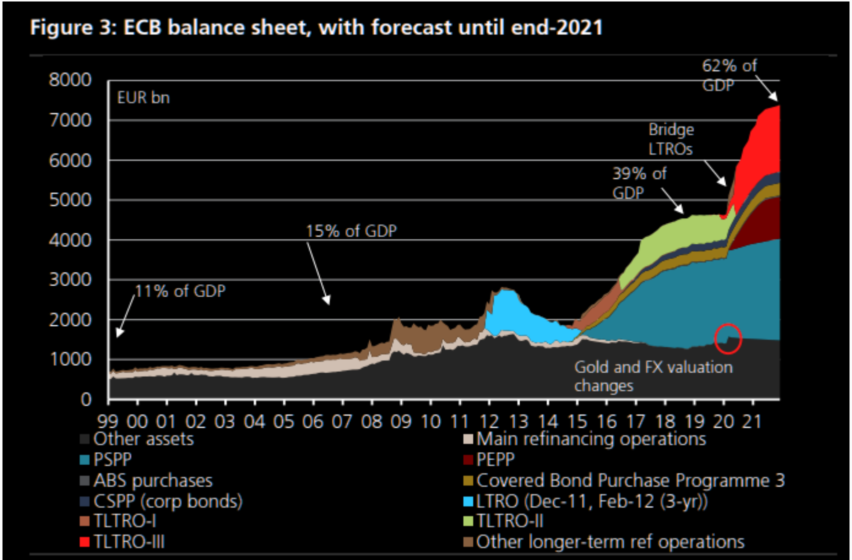
CET1



LEV



ECB Balance sheet



Structural Break

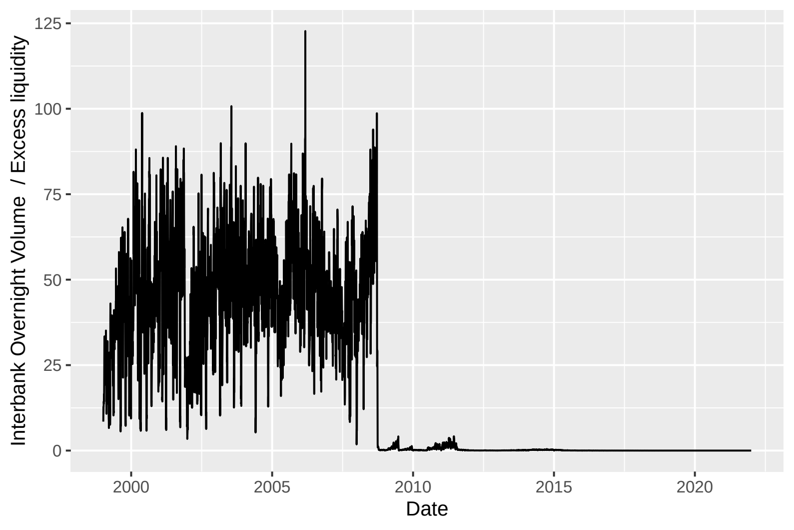
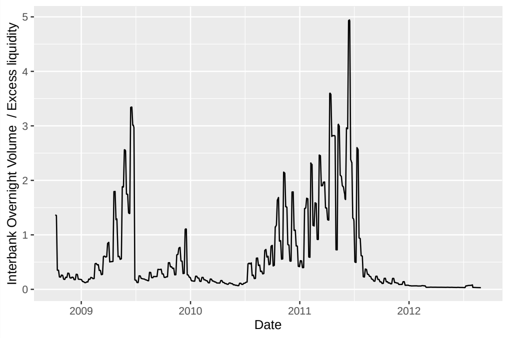
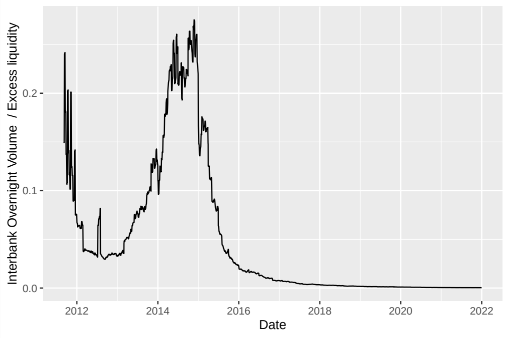


Figure: Overnight reserves market volume expressed as a multiple of excess liquidity

Structural Break 2



(a) Structural break: Eurocrisis



(b) Structural break: LSAP

Figure: Overnight interbank market volume as a multiple of excess liquidity

Back

Unsecured Bank Debt

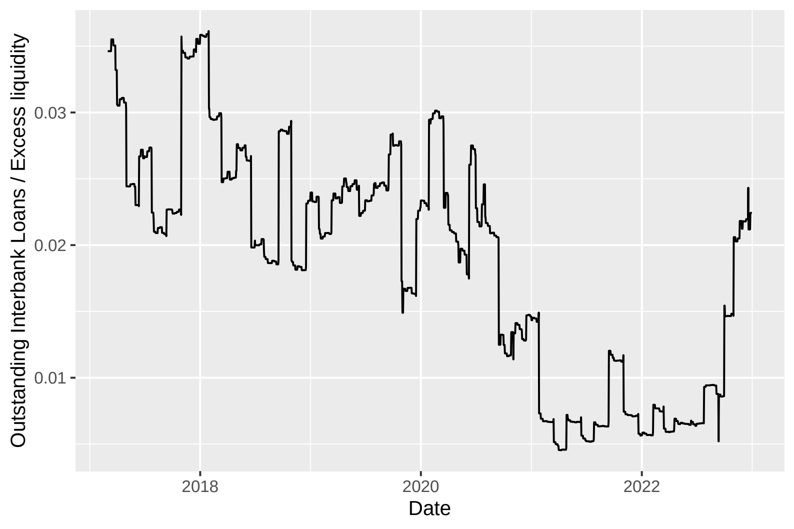
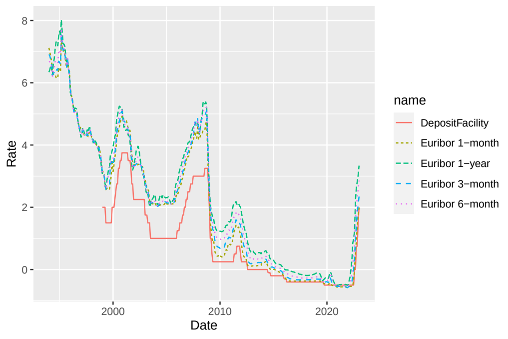
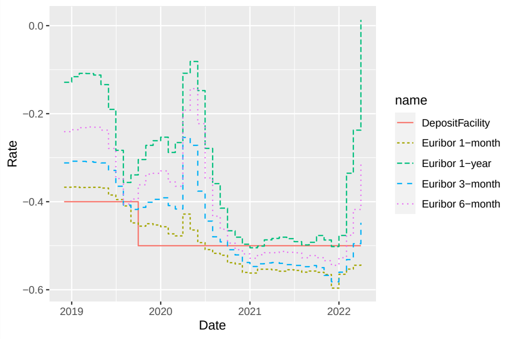


Figure: Outstanding Unsecured Inter-Bank Debt As a Fraction of Reserves

Rates inversion



(a) Euribor vs Deposit facility rate



(b) Euribor vs Deposit facility rate: Zoom

Figure: Euribor plotted against the deposit facility rate

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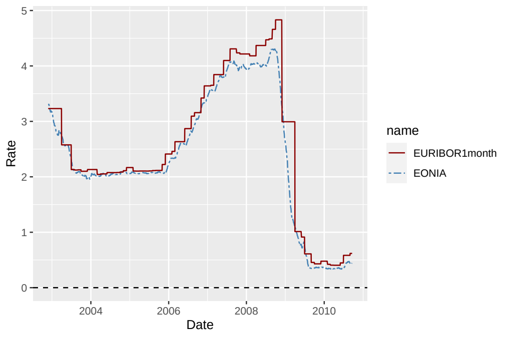
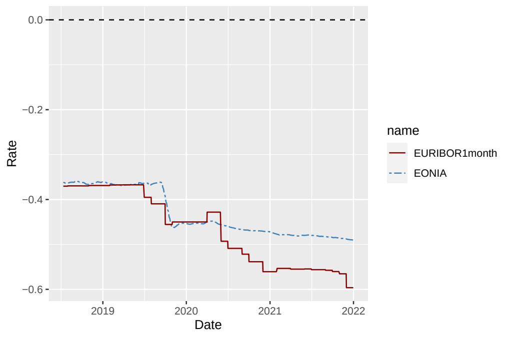
Rates inversion 2



(a) Rates pre unconventional monetary policy



(b) Rates post unconventional monetary policy

Figure: The market for reserves

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First Order Conditions

The F.O.C.s yield that marginal revenue (LHS) equals marginal cost (RHS)

$$
\begin{aligned}
&-\varphi \Delta Q_{i,R} = R_{ITB} - R_{DF} + \frac{\partial C_i}{\partial \Delta Q_{i,R}} \\
&\frac{\partial \mathsf{R}_{i,L}}{\partial \mathsf{L}_i} \mathsf{L}_{i,l} + \mathsf{R}_{i,l} = \frac{\partial C_i}{\partial \mathsf{L}_i} \\
&\mathsf{R}_S = \frac{\partial C_i}{\partial \mathsf{S}_i} \\
&-\frac{\partial R_{i,d}}{\partial D_i} D_i - R_{i,d} = \frac{\partial C_i}{\partial D_i}
\end{aligned}
$$

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Agnostic cost function

If we take the agnostic approach, then we take the cost function to be a second order polynomial of the interaction of balance sheet items.

Let us define BS as the stacked vector of balance sheet items, $\mathbf{BS} = \begin{cases} S_i \\ L_i \\ Q_{i,R} - \Delta Q_{i,R} \\ E_i \\ D_i \end{cases}$

$$C(Q_{i,R}, \mathbf{X}_i(\mathbf{R}_{i,X}), D_i(R_{i,d})) = \mathbf{BS}'\Lambda\mathbf{BS} + \lambda\mathbf{BS}$$

With Λ, λ to be estimated. Back

Loan demand

Let $L_{i,nt}$ represent the share of bank i in market n at time t:

$$L_{i,nt} = \bar{F}_{L,nt} \int_{\mathcal{J}} \frac{\exp(\alpha_{L,j} r_{L,i,nt} + \beta_L x_{L,i,nt} + \delta_{L,i,nt})}{1 + \exp(\theta_n + \alpha_{B,j} r_{DF,t}) + \sum_{k \in \mathcal{I}} \exp(\alpha_{L,j} r_{L,k,nt} + \beta x_{L,k,nt} + \delta_{L,k,nt})}$$

With

- $\bar{F}_{L,nt}$ the size of the market, .
- $\alpha_{B,j} < 0$ the heterogeneous elasticity of bond issuance to the risk free rate r_{DF} and θ_n the base utility of bond issuance.
- $\alpha_{L,j} < 0$ the heterogeneous elasticity of demand for loans to the interest rates on loans $r_{L,i,nt}$
- β_L the population coefficients on bank-market characteristics $x_{L,i,nt}$
- $\delta_{L,i,nt}$ a bank-specific intercept parameter

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Potential Instruments

We require an instrument $z_{i,nt}$ that impacts banks' interest rate choices but is not correlated with unobserved quality $\varepsilon_{i,nt}$.

1. Immigration shock à la Bartik
2. Natural disasters
3. A local public spending shock (Pinardon-Touati 2022)
4. Instrument à la BLP, that is the the characteristics of the competitors at the local or national level

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Sketch of Estimation

Estimation revolves around a two-pass mechanism. We describe the estimation for the deposit market, but the mechanism is similar in other markets.

1. A first pass would estimate initial demand parameters using linear IVs, following the process described in Diamond et al. (2022)
2. Using these parameters we can compute $\hat{\psi}_{nt}$, which we can then use to estimate $\bar{F}_{D,nt}$ through linear IVs.
3. Now that we have a value for $\bar{F}_{D,nt}$ and a starting estimate for demand system parameters, we can start the second pass and run BLP to properly estimate the equation

$$D_{i,nt} = \bar{F}_{D,nt} \int_{\mathcal{J}} \frac{\exp(\alpha_{D,j} r_{D,i,nt} + \beta_D x_{D,i,nt} + \delta_{D,i,nt})}{1 + \exp([\gamma_n + \alpha_{f,j}] r_{DF,t}) + \sum_{k \in \mathcal{I}} \exp(\alpha_{D,j} r_{D,k,nt} + \beta_D x_{D,k,nt} + \delta_{D,k,nt})}$$

   through GMM. It is still necessary to use IVs that are susceptible to shift the bank rates to properly estimate the elasticity parameters.
4. We then estimate the balance-sheet cost parameters at the bank level through GMM or IV.

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QE in two tiered monetary system (1/2)

Central Bank

Securities	Liabilities
Assets	Reserves
IOU	
+ Securities	+ Reserves

Bank

Assets	Liabilities
Securities	Capital
Loans	Deposits
− Securities	
+ Reserves	

Table: QE Trade when a bank is the direct counterparty of the central bank

Back to slide 1 Back to Facts

QE in two tiered monetary system (2/2)

Central Bank

Assets	Liabilities
Securities	Reserves
IOU	
+ Securities	+ Reserves

Bank

Assets	Liabilities
Securities	Capital
Loans	Deposits
+ Reserves	+ Deposits

Non-Bank

Assets	Liabilities
Securities	Capital
Deposits	Loans
− Securities	
+ Deposits	

Table: QE Trade when a bank is the intermediary of the counterparty

Back to slide 1 Back to Facts Back to reduced form

Datasets in detail (1)

- **SHS-France** contains detailed security by security holdings by sectors (Banks, Households, etc.) in France. It includes information on the price and characteristics of these securities.
- **M-INTDEPO** reports bank-by-bank aggregate amounts for deposit products and the related monthly interest rate flows. This allows for the computation of interest rates paid by French banks on their deposit products.
- **M-INTENCO** reports bank-by-bank aggregate amounts for lending products and the related monthly interest rate flows. This allows for the computation of interest rates charged by French banks on their lending products.
- **IMIR-ENCOURS** reports bank-by-bank aggregate lending, and interest rate flows. Back

Datasets in detail (2)

- M-RESEAUG reports aggregate lending and deposits for bank branches, for various counterparty categories. It specifically includes loans to state entities.
- ITB-nRESI-EC, ITB-RESID-EC reports secured and unsecured exposures (in different currencies) to interbank lending and deposits, both towards ECB and other credit institutions.
- M-TITPRIM reports bank-by-bank aggregate holdings for different security and counterparty types. Both the accounting value and the market value of the assets can be observed in the dataset.
- ENGAG-INT reports the international exposure of the bank, country-by-country, instrument-by-instrument.
- M-CONTRAN includes new euro-denominated credit contracts issued by French banks concluded with nonbanks. Provides the amount and the interest rates of the reported loans, with unique loan identifier. Back

Datasets in detail (3)

- **COTA**: The dataset reports the company ratings issued by the Banque de France, which in combination with the credit registry allows to gauge the riskyness of the lending portfolio of banks.
- **NCE**: Subsample of new lending contracts matched with data on the borrowing companies (size, credit risk).
- **SCR**: Credit registry. Collects data on borrowers with exposure above 25,000 euros towards banks operating in France. It reports outstanding amount of credit, interest rates, as well as the geographic location of borrowers.
- **SITUATION-EC**: Banks' balance sheet items obtained from bank regulatory filings. Provides a summary of activities by operation and geographical area.
- **M-SITMENS**: Monthly aggregate banks' balance sheet items. The level of detail is lower than in the SITUATION-EC dataset.

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European Specificities

European Banks

1. Can fund whole portfolio of assets with deposits: potential substitution between lending and investment banking
2. Faced negative interest rates on excess reserves
3. Most banks can hold reserves: Under large excess reserves, the market for reserves vanishes
4. LTRO programs

To the best of our knowledge, no structural model addresses these issues.

Basel III regulatory framework

Capital regulation LEV CET1

$$RWC = \frac{Common\ equity}{Risk\ weighted\ assets\ (RWA)} > 1$$

$$Equity\ ratio = \frac{Common\ equity}{Total\ Exposure} > \delta$$

Liquidity regulation LCR NSF

$$LCR = \frac{High\ quality\ liquid\ asset\ amount\ (HQLA)}{Total\ net\ cash\ outflow\ amount\ during\ stress} > 1$$

$$NSF = \frac{Available\ amount\ of\ stable\ funding}{Required\ amount\ of\ stable\ funding} > 1$$

Data

Banque de France

- Credit registry, french banks balance sheets, deposits and rates, interbank exposures
- Monthly to quarterly data
- Cannot interact these datasets with private data

BankFocus

- Balance sheet items of banks in the Eurozone
- Yearly Data

Datasets in detail Back

The demand function

Bank compete à la Bertrand in n imperfect markets.

WLOG, deposit market: $D_{i,nt}$ representing the share of bank i in market n at time t:

$$D_{i,nt} = \bar{F}_{D,nt} \int_{\mathcal{J}} \frac{\exp(\alpha_{D,j} r_{D,i,nt} + \beta_D x_{D,i,nt} + \delta_{D,i,nt})}{1 + \exp(\gamma_n + \alpha_{f,j} r_{DF,t}) + \sum_{k \in \mathcal{I}} \exp(\alpha_{D,j} r_{D,k,nt} + \beta_D x_{D,k,nt} + \delta_{D,k,nt})}$$

With

- $\bar{F}_{D,nt} = \int_{\mathcal{J}} \mu_j$ the size of the market.
- $\alpha_{f,j} > 0$ elasticity of demand to the risk free rate r_{DF}
- γ_n a parameter that governs the outside option for market n.
- $\alpha_{D,j} > 0$ the elasticity of demand to the interest rates on deposits $r_{D,i,nt}$
- β_D the general coefficients on bank-market characteristics $x_{D,i,nt}$
- $\delta_{D,i,nt}$ a bank-specific intercept parameter

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Instruments

Financial clientele : exposure to third-party QE sales

- Proportion of assets allocated to loans to financial corporations
- Proportion of liabilities constituted by deposits from financial corporations Back

IV FIRST STAGE

Dependent Variables:	Reserve Share (lag)	Reserve Share Change	Δ Reserves
Model:	(1)	(2)	(3)
Variables			
Financial Loans	-0.8653***	-0.3124***	-22.50***
	(0.0564)	(0.0525)	(2.225)
Financial Deposits	0.4586***	-0.0774***	2.656***
	(0.0806)	(0.0194)	(0.7086)
FinL$\times$ FinD	40.60***	39.37***	1,245.0***
	(3.276)	(2.645)	(111.5)
Fit statistics			
Observations	866,202	866,202	866,202
R^2	0.53425	0.49504	0.57812
Within R^2	0.26445	0.18959	0.06002

Counterfactuals computation recipe

0. Fix the shock – be it a change in the structural parameters, a change in the regulatory constraints, a change in the quantity of reserves, etc.
1. Guess assets $\mathbf{A}$ and liabilities $\mathbf{L}$. From the guess, compute traded reserves equilibrium $\tilde{Q}_R$.
2. Compute the marginal cost for each bank-level item using the vector guessed assets and liabilities $\{A, L\}$ and the computed reserves equilibrium $\mathbf{Q_R}$
3. Compute $\boldsymbol{\lambda}_{BS}$, the vector of estimated $\hat{\lambda}_{BS,i}$, by taking for $j \in \mathcal{J} \setminus \{Loans, Deposits\}$

$$\hat{\lambda}_{BS,i} = \frac{\sum_j MC_{i,j} - MR_{i,j}}{|\mathcal{J} \setminus \{Loans, Deposits\}|_i}$$

4. Find the market rates for each $j \in \{Loans, Deposits\}$, that ensure $MC_{i,j} - MR_{i,j} = \hat{\lambda}_{BS,i}$
5. For $j \in \mathcal{J} \setminus \{Loans, Deposits\}$, compute the quantities solving $\hat{\lambda}_{BS,i} = MC_{i,j} - MR_{i,j}$.
   For $j \in \{Loans, Deposits\}$, compute the demand-side quantities implied by the market rates (from the market equilibrium).
6. Update the initial guess using the quantities $\hat{\mathbf{A}}, \hat{\mathbf{L}}$ computed in step 5 and the Jacobian of the functions defining steps 1-5. This yields an updated guess $\{\mathbf{A}', \mathbf{L}'\}$ Iterate over until convergence (i.e. $\{\mathbf{A}, \mathbf{L}\} = \{\mathbf{A}', \mathbf{L}'\}$).

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Counterfactuals computation: in a nutshell

1. $f_1 : \{\mathsf{A}, \mathsf{L}\} \mapsto \{\mathsf{A}, \mathsf{L}, \tilde{Q}\}$
2. $f_2 : \{\mathsf{A}, \mathsf{L}, \tilde{Q}\} \mapsto \{\mathsf{A}, \mathsf{L}, \tilde{Q}, \mathsf{MC}_\mathsf{A}, \mathsf{MC}_\mathsf{L}\}$
3. $f_3 : \{\mathsf{A}, \mathsf{L}, \tilde{Q}, \mathsf{MC}_\mathsf{A}, \mathsf{MC}_\mathsf{L}\} \mapsto \{\mathsf{A}, \mathsf{L}, \tilde{Q}, \mathsf{MC}_\mathsf{A}, \mathsf{MC}_\mathsf{L}, \hat{\boldsymbol{\lambda}}_{BS}\}$
4. $f_4 : \{\mathsf{A}, \mathsf{L}, \tilde{Q}, \mathsf{MC}_\mathsf{A}, \mathsf{MC}_\mathsf{L}, \hat{\boldsymbol{\lambda}}_{BS}\} \mapsto \{\mathsf{MC}_\mathsf{A}, \mathsf{MC}_\mathsf{L}, \mathsf{MR}_\mathsf{A}, \mathsf{MR}_\mathsf{L}, \hat{\boldsymbol{\lambda}}_{BS}\}$
5. $f_5 : \{\mathsf{MC}_\mathsf{A}, \mathsf{MC}_\mathsf{L}, \mathsf{MR}_\mathsf{A}, \mathsf{MR}_\mathsf{L}, \hat{\boldsymbol{\lambda}}_{BS}\} \mapsto \{\mathsf{A}, \mathsf{L}\}$

A fixed point of $f = f_1 \circ f_2 \circ f_3 \circ f_4 \circ f_5$ defines an equilibrium of the system.

By the chain rule,

$$J_f = J_{f_1} \times J_{f_2} \times J_{f_3} \times J_{f_4} \times J_{f_5}$$

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